THE EFFECT OF ELECTRODES MADE OF DIFFERENT METALS ON THE SKIN CURRENTS

BY

E. W. MARCHANT AND H. WALLACE JONES

From the Department of Electrical Engineering in the University of Liverpool and the Heart Department of the Liverpool Royal Infirmary

Received December 12, 1939

The use of metal electrodes combined with some form of conducting jelly has become almost universal in recent years, largely on account of their convenience over the former non-polarizable type of electrodes, and also to a lesser degree owing to the more frequent use of lead IV. The metal used in the construction of the electrode itself varies considerably and we think that the importance of choosing the most suitable metal for these electrodes has not been sufficiently realized, especially when using one of the older types of electrocardiograph machines in which the skin current is neutralized by means of a compensating current, i.e. not the modern condenser model.

Attention was first drawn to the large skin currents that were produced, when a new series of electrodes was constructed for recording lead IV. All these electrodes were of equal size and consisted of brass discs, 1·125 in. in diameter ; they were all chromium-plated in order to improve their appearance. When tried on a patient, it was found, however, that the skin current varied considerably ; and also that if there was, with one pair of electrodes, a very large skin current in one direction, the current flowed with equal intensity in the opposite direction when the electrodes were reversed ; this showed that the skin current was produced by the electrode itself and was not dependent upon any peculiarity of the patient. The skin currents were frequently so large that it was impossible to neutralize them by the compensating current.

A rough test with the chromium-plated electrodes showed that when a cloth, moistened with jelly, was placed between certain pairs of electrodes there was a considerable current that varied with individual electrodes : the direction of the current could be reversed by reversing the electrodes. When brass electrodes were used, less current was produced as a rule, but the amount was still considerable.

A number of experiments were carried out to investigate this variability in the skin currents with electrodes made of different metals, and also the changes that took place with electrodes made of the same metal.

The following materials were tried : (1) brass ; (2) German silver ; (3) tin-coated brass ; and (4) tin.

VOLTAIC E.M.F. DUE TO THE ELECTRODES

The electrodes were tested by putting them on a moistened cloth, which rested on a brass plate, and the arrangement for making the tests is shown in Fig. 1. Two solutions were employed for soaking the cloth :

(1) Cambridge electrode jelly ;

(2) a gum tragacanth solution containing about 25 per cent. of salt (R.I. jelly).

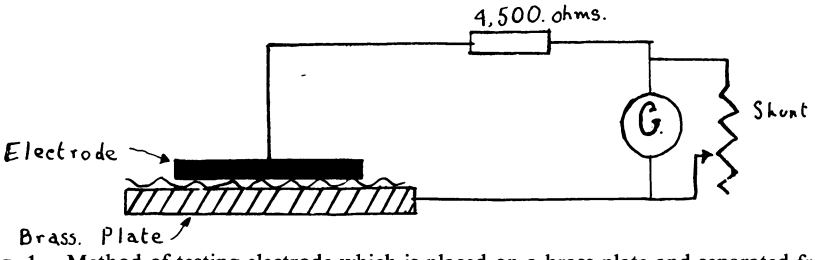

FIG. 1.—Method of testing electrode which is placed on a brass plate and separated from it by a layer of moistened cloth.

The results are given in Table I, and the last column shows the number of millivolts between a brass plate and the electrode, due to the solution employed for soaking the cloth. This was estimated from the current passing

TABLE I

E.M.F. DEVELOPED WITH ELECTRODES OF DIFFERENT METALS

Type of Electrode	Electrolyte	Millivolts
Brass No. 1	R.I. Jelly	11·1
Brass No. 2	R.I. Jelly	2·4
German silver No. 1	R.I. Jelly	135
German silver No. 2	R.I. Jelly	137
German silver No. 1	Cambridge Jelly	105
German silver No. 2	Cambridge Jelly	98
Tin No. 1	R.I. Jelly	150
Tin No. 2	R.I. Jelly	150
Brass (tin-plated) No. 1	R.I. Jelly	145
Brass (tin-plated) No. 2	R.I. Jelly	146

through the galvanometer and the resistance of the circuit. The electrodes were then tried in pairs, with the cloth soaked in jelly between, as shown in Fig. 2.

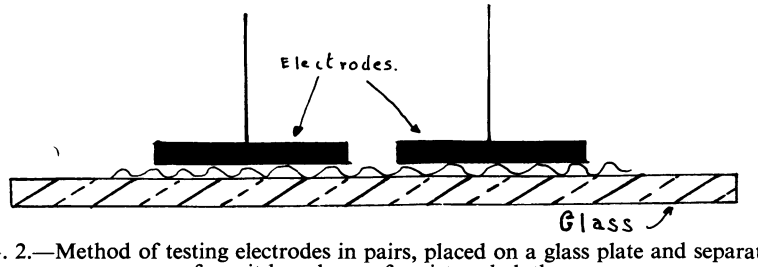

FIG. 2.—Method of testing electrodes in pairs, placed on a glass plate and separated from it by a layer of moistened cloth.

The voltage was measured between pairs of similar electrodes. In making

the tests, the electromotive force was measured after allowing the current produced by the voltaic action of the electrodes to pass for a considerable time until steady conditions had been obtained. In some cases it was noticed that the current did not reach a steady value until three or four minutes after the connection had been completed, the current generally increasing to a steady value. Two brass electrodes, cut from the same piece of thin brass, showed a large difference in the voltaic electromotive force, which was apparently due to slight differences in the composition of the brass. Chromium-plated electrodes also gave variable results, which appeared to be due to slight irregularities in the chromium-plating. German silver electrodes of one type gave fairly satisfactory results, but these were not uniform and depended upon the nature of the alloy used for the German silver. It was suggested that tin electrodes might be used and these were found to be very satisfactory. It will be noticed that the voltage between a tin electrode and the brass plate (Table I) is considerably higher than with some of the other metals. The difference between the E.M.F. due to each of the two tin electrodes, however, is less than it is between any of the other pairs of electrodes. These results are shown in Table II :

TABLE II

E.M.F. BETWEEN PAIRS OF ELECTRODES

Type of Electrode	Electrolyte	Millivolts
Brass No. 1 and 2	Cambridge Jelly	8·4
Brass No. 1 and 2	R.I. Jelly	4·1 to 8·4*
German silver No. 1 and 2.. ..	Cambridge Jelly	7·0 to 12·0
German silver No. 1 and 2.. ..	R.I. Jelly	1·5 to 2·6
Tin No. 1 and 2	R.I. Jelly	$<1·0$
Brass (tin plated) No. 1 and 2 ..	R.I. Jelly	0·6 to 2·5*

* After rubbing.

There is, therefore, a smaller " electrode effect " with tin electrodes than with the other metals. The variations in zero observed on the cardiograph are negligibly small with tin electrodes and do not change to any appreciable extent during the taking of a cardiogram. Although tin was found to be the most satisfactory metal from this point of view, the voltaic E.M.F. between it and brass is very considerable, and it seemed likely that a more inert metal, like lead, might be used with advantage. The difficulty, however, with lead is that the surface tends to oxidize and requires frequent cleaning if good contact is to be made with the skin.

APPARENT RESISTANCE BETWEEN ELECTRODES THROUGH CLOTH SOAKED IN JELLY

There was found to be a considerable difference, with the different electrodes, in the electrical resistance between the electrode and a brass plate with cloth soaked in jelly to separate them. The electrodes were, as before, circular discs, 1·125 in. in diameter. This resistance was due apparently to a surface resistance effect. The results are shown in Table III and were measured with the arrangement shown in Fig. 3. The voltaic E.M.F. produced by the electrode was used

to send current through the galvanometer, and two readings were taken—one with the galvanometer alone and the other with a millivoltmeter of 500 ohms resistance shunted on it. With this arrangement it is easy to calculate the effective resistance between the electrode and the brass plate. The differences are very large, the tin and tinned brass giving much the lowest values. The increased resistance would seem likely to be due to the formation of films on the surface of the electrodes, which offer a large resistance to the passage of the current in the case of brass and German silver.

TABLE III

RESISTANCE BETWEEN VARIOUS METAL ELECTRODES AND A BRASS PLATE

Type of Electrode	Electrolyte	Approximate Value of Resistance in Ohms.
Brass	R.I. Jelly	230
German silver (1)	R.I. Jelly	4,000
German silver (2)	R.I. Jelly	12,000
Tin	R.I. Jelly	90
Tinned brass	R.I. Jelly	80

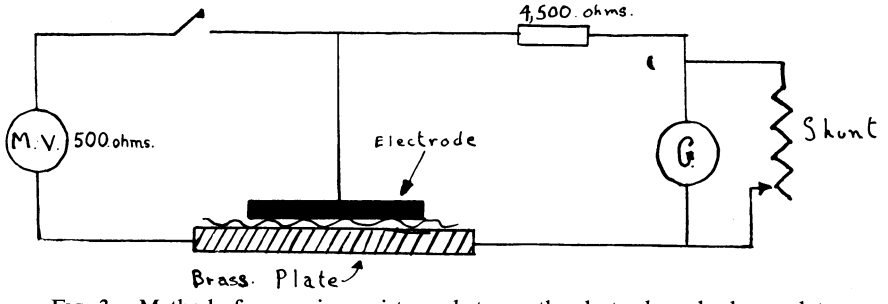

FIG. 3.—Method of measuring resistance between the electrode and a brass plate separated by a moistened cloth.

The jelly that has been used in our latest work was similar to the R.I. jelly mentioned previously with the addition of powdered pumice stone; it consisted of:

Sodium chloride	30 g.
Powdered tragacanth	3 g.
Powdered pumice stone	1 g.
Water	85 c.c.

SUMMARY

(1) These experiments show the value of tin electrodes in diminishing the amount of the skin currents, and suggest that tin is the most satisfactory material for electrodes.

(2) The superiority of tin electrodes did not appear to be due to the fact that they gave a smaller skin current than the others, but rather to this current being much more constant than with the other metals; in consequence when two electrodes were paired the two currents balanced each other.

(3) The surface resistance of tin electrodes is smaller than that of the other metals.

(4) Almost equally good results can be obtained with brass electrodes that had been heavily tin-coated; as these are more easily made and less expensive than the pure tin, they are now being used almost exclusively.